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SONAR TRANSDUCER VIBRATION REQUIREMENTS AND MEASUREMENT TECHNIQ--ETC(U)
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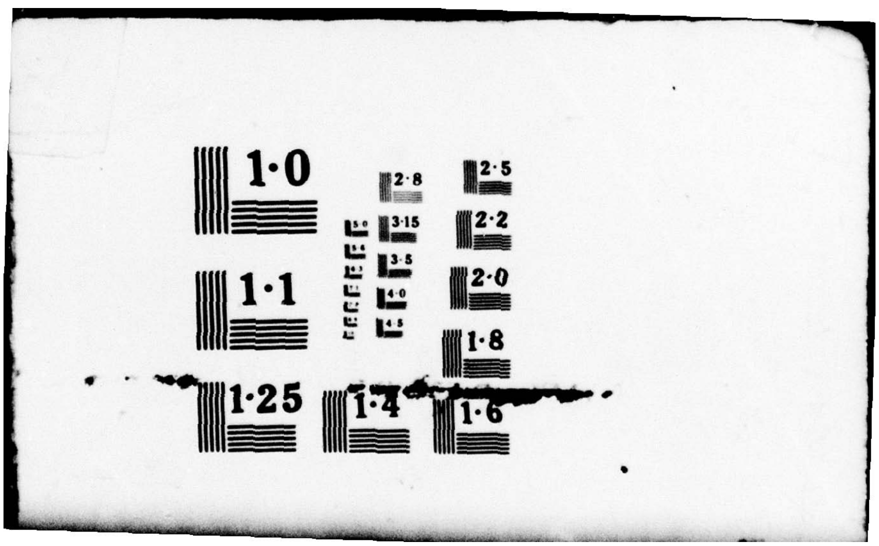
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(6) SONAR TRANSDUCER VIBRATION REQUIREMENTS AND MEASUREMENT TECHNIQUES.

by

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By its very nature, a sonar transducer has a multitude of vibration problems not present in other types of equipment. These problems dictate the use of isolation concepts and measurement techniques basically different from those used in conventional vibration work. to pg. 6

A sonar transducer is a device for transforming a time-varying pressure signal into an electrical signal at the output terminals, or conversely, creating a time-varying pressure field from an electrical input. This is usually accomplished by means of a piezoelectric ceramic element arranged in a manner that gives the desired projecting or receiving characteristics. Since the receiving characteristics are far more sensitive to vibration phenomena, all subsequent discussion will be directed to passive hydrophones or projectors operated in a passive mode.

Consider a basic hydrophone consisting of a hollow piezoelectric ceramic cylinder. The ceramic is polarized in such a way that any induced strain in the ceramic will cause a potential across the output terminals. If this hydrophone is placed in a time-varying acoustic field or pressure field, an electrical signal proportional to the field can be detected at the output terminals. However, since the ceramic has finite mass, any motion of the ceramic causes inertial loading and the hydrophone

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also acts as an accelerometer. Signals resulting from the acceleration effect constitute a part of the hydrophones undesirable characteristics.

Since a vibrating hydrophone moves in a fluid such as water, there will be a force exerted on the ceramic proportional to the velocity of the motion. This force, which is called radiation pressure, is due to the relative motion between the fluid and the hydrophone and results in a second component of undesirable background noise.

Noise may also be induced from any booting material placed over the ceramic for protection since it, too, has inertial loading which causes a strain in the ceramic and therefore an output voltage. This booting effect is very difficult to separate from a pure accelerometer effect of the ceramic, but it is nonetheless part of the total noise signal.

There may be noise radiated from the mounting points of the hydrophone and received as acoustic noise at the ceramic. This is a major problem when designing a hydrophone mount since any radiated noise is very close to the hydrophone and is easily detected.

In theory, the accelerometer effect can be cancelled by another cylinder positioned inside the existing cylinder with equivalent sensitivity but opposite polarity. The resonant frequencies of the ceramic mountings must be held very nearly equal such that the two signals are always 180° out of phase and of equal amplitude. This is a problem without a solution as yet, since any small phase shift in one ceramic but not in the other results in a signal impossible to cancel.

The next alternative would be to isolate the hydrophone from any vibration at its mounting point. The hydrophone would remain motionless in the acoustic field and measure only the time-varying pressure signal. This approach would eliminate the accelerometer effect and the radiation pressure effect. The problem now is that the acoustic energy from near structure is worse since the <u>relative</u> motion between the hydrophone and the near structure has been increased. The increased relative motion can only be eliminated by eliminating the ship's vibration or by adding pressure release material on any surface that could radiate sound to the hydrophone, the latter technique being only partially successful.

In order to compare hydrophones for vibration response, whether they are hydrophones of the same type or otherwise, a standard measurement technique was developed. The quantity measured is known as Hydrophone Vibration Response, or more simply, H.V.R. This is the ratio in dB of the hydrophone output to the acceleration input referred to the mounting

point. The units are in terms of sound pressure levels (ubars) to acceleration units (g's). The final curve is a normalized vibration response curve.

Hydrophones that are subjected to this test are operated in air and in water. The acceleration input levels are maintained as near as possible to actual ship vibration levels measured in the vicinity of the transducer mounting point. These levels are usually very low and on the order of -60 dB//1g-peak (.001g) or less.

The hydrophone and its mounting bracket are attached to a fixture which is attached to a small, low level vibration exciter such as shown in Fig. 1. The input acceleration is monitored by the accelerometer on the fixture.

For a normal swept sine test, the entire setup is run in air, and curves of acceleration input, hydrophone output, and the ratio of hydrophone output to input acceleration are taken. This procedure establishes the acceleration response of the hydrophone. The radiation pressure is very low in air, and the sound radiated from near structure is not picked up so that the air test shows the pure acceleration response. This test shows any resonances in the hydrophone itself or in its mounting. Internal resonances in the hydrophone will not change when the hydrophone is in water, but bracket resonances will be lowered because of the increase in apparent mass of the bracket. If acceleration cancelling has been added, the air test will show how successful the cancelling effect is working. With acceleration cancelling added, a decrease in level of about 20 dB might be expected during the air test.

The next test to be performed would be a test with the hydrophone alone in water. The water surface should be maintained between the hydrophone and the bracket. This test adds the radiation pressure signal in the resulting H.V.R. curve. The acoustic energy radiated from the bracket is not detected by the hydrophone because of the impedance mismatch between air and water. At some frequencies the resulting curve may be lower than the pure acceleration response because of destructive interference between the acceleration effect and the radiation pressure effect.

The last curve and most important curve is taken with the bracket and hydrophone under water. This curve now includes all the components of the hydrophone's vibration response. The radiated noise from the

bracket is now water-coupled, and the hydrophone output is approximately the same as it would be on the side of a ship. The curve does not include, however, the sound radiated from the ship's structure near the hydrophone, which is, in fact, a major source of interfering signal. Curves from each of the three tests are shown in Fig. 2. The substantial increase in level when the bracket is underwater with the hydrophone indicates that the sound pressure level seen by the hydrophone indicates that the sound pressure level seen by the hydrophone is actually water-coupled radiated noise.

With the three different H.V.R. curves, the sources of vibration problems are more easily isolated. An acceleration response problem would show up in the first curve, whereas a geometry dependent radiation pressure problem should be detected in the second curve. The problem of bracket-generated noise would be seen in the third curve.

The example shown is only one of many types and shapes. The radiation pressure was not a large problem with the cylindrical shape. The problem with this hydrophone, as far as its vibration response is concerned, is its bracket. The nearness to the hydrophone allows any vibratory motion of the bracket to be water-coupled directly. Perfect isolation from the bracket does not improve the overall response, as can be seen in Fig. 3. Perfect isolation in this case is achieved by suspending the hydrophone on shock cord and positioning the bracket over the hydrophone with no physical connection. The energy received by the hydrophone is now entirely water-coupled. The curve shows that the average level of the perfectly isolated hydrophone is very nearly the same as the hydrophone in its normal mount.

The next possible alternative for the particular mounting condition would be a rigid mount. This approach would eliminate the isolation provided by the normal mount, which resulted in relative motion between the bracket and the hydrophone.

For the hydrophone referred to in the example, a rigid bracket was constructed of 1/2-inch thick aluminum plate. The distance from the hydrophone to the bracket was the same as with the normal mount. The resulting curves indicate that for some frequency bands, a rigid mount for this hydrophone would be the best choice. A comparison of the curves is shown in Fig. 4.

The decision as to which bracket would be more suitable would depend on several conditions. For example, the bracket and hydrophone also have to meet shock requirements. A rigid bracket might result in

mechanical damage to the ceramic, whereas a very compliant bracket may not possess sufficient strength to retain the hydrophone during shock.

Another important consideration is the frequency range of interest for the hydrophone. It might be that one bracket is clearly better than another over the range of interest for the hydrophone but is much worse in other frequency bands. Since in the actual environment the excitation is random, the desired signal may be difficult to distinguish with high noise levels present in other frequency bands. If, for example, the hydrophone was used for frequencies between 100 and 600 Hz, the rigid bracket might be the best choice.

Since random excitation is characteristic of the shipboard environment, H.V.R. curves may be taken with shaped random excitation. The spectrum of the input acceleration can be matched to an actual ship vibration spectrum taken from sea tests. Since the output of the hydrophone is quite linear with input acceleration, the results of a swept sine test and a random test compare favorably. It is therefore possible to conduct laboratory tests by using the swept sine technique, providing the test input levels are maintained fairly near the actual input levels. It is necessary to maintain a realistic input because the bracket mounting points are somewhat non-linear with input amplitude.

In our particular case, the H.V.R. curves are taken at the USL Transducer Vibration Laboratory. The hydrophone and bracket under test are fixtured and excited by a small reaction-type shaker. The control accelerometer is either servo-controlled or equalized to provide a response similar to actual sea test acceleration levels.

The hydrophone and acceleration signals are then analyzed by narrow band tracking filters. The ratio of the two amplitudes is taken by what is basically a Mechanical Impedance and Power Spectral Density (PSD) analysis system. The log of the DC voltage proportional to each signal is taken, and the difference between the hydrophone and acceleration signal is plotted as the ratio of hydrophone output to acceleration input. The units are ubars/peak g when the sensitivities of each device are accounted for.

The system used in the Transducer Vibration Laboratory is a Spectral Dynamics PSD and Mechanical Impedance analog analyzer shown in Fig. 5. There is additional capability of four simultaneous analysis channels with constant bandwidth filters. The available

filter bandwidths are 2, 5, 10, 20, 50, and 100 Hz, which may be automatically switched at predetermined frequencies. Available also is variable time averaging and bandwidth correction shift for PSD analysis. In the impedance mode, phase angle and artificial integration may be performed on incoming signals to find mechanical impedance, or mobility, apparent mass, compliance, etc.

Adjacent to the analysis equipment is a large elliptical wooden test tank for underwater tests. The tank is isolated on low frequency air mounts to attenuate ground induced vibration and is ten feet by twelve feet by nine feet deep.

This facility has been established at the Underwater Sound Laboratory specifically for the purpose of investigating sonar transducer vibration characteristics. Only sporadic work has been done in the past in this investigative area, and the understanding gained through present efforts is expected to yield significant improvements in the performance of transducers.

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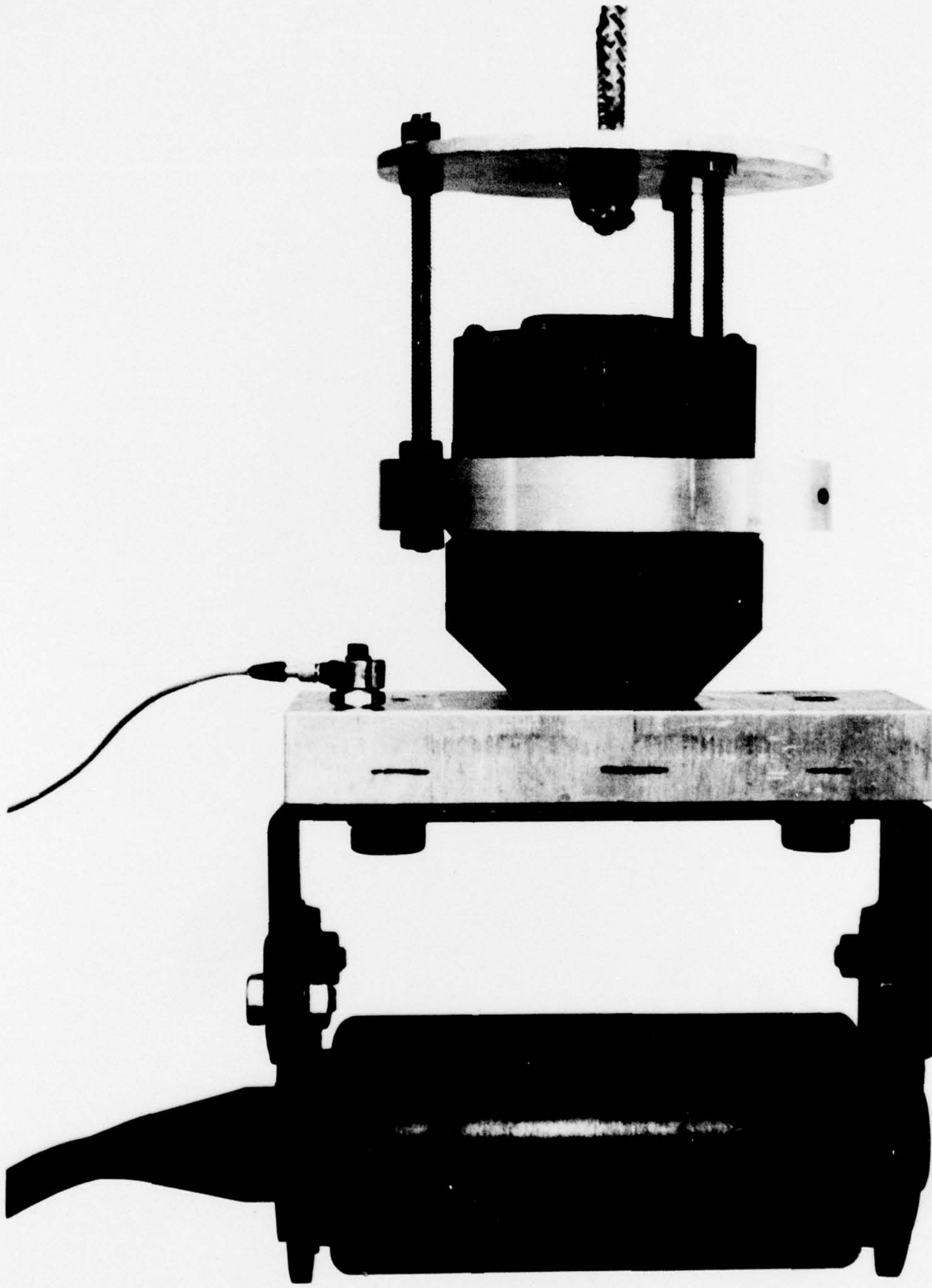

Fig. 1 - Hydrophone Set Up for Vibration Measurements

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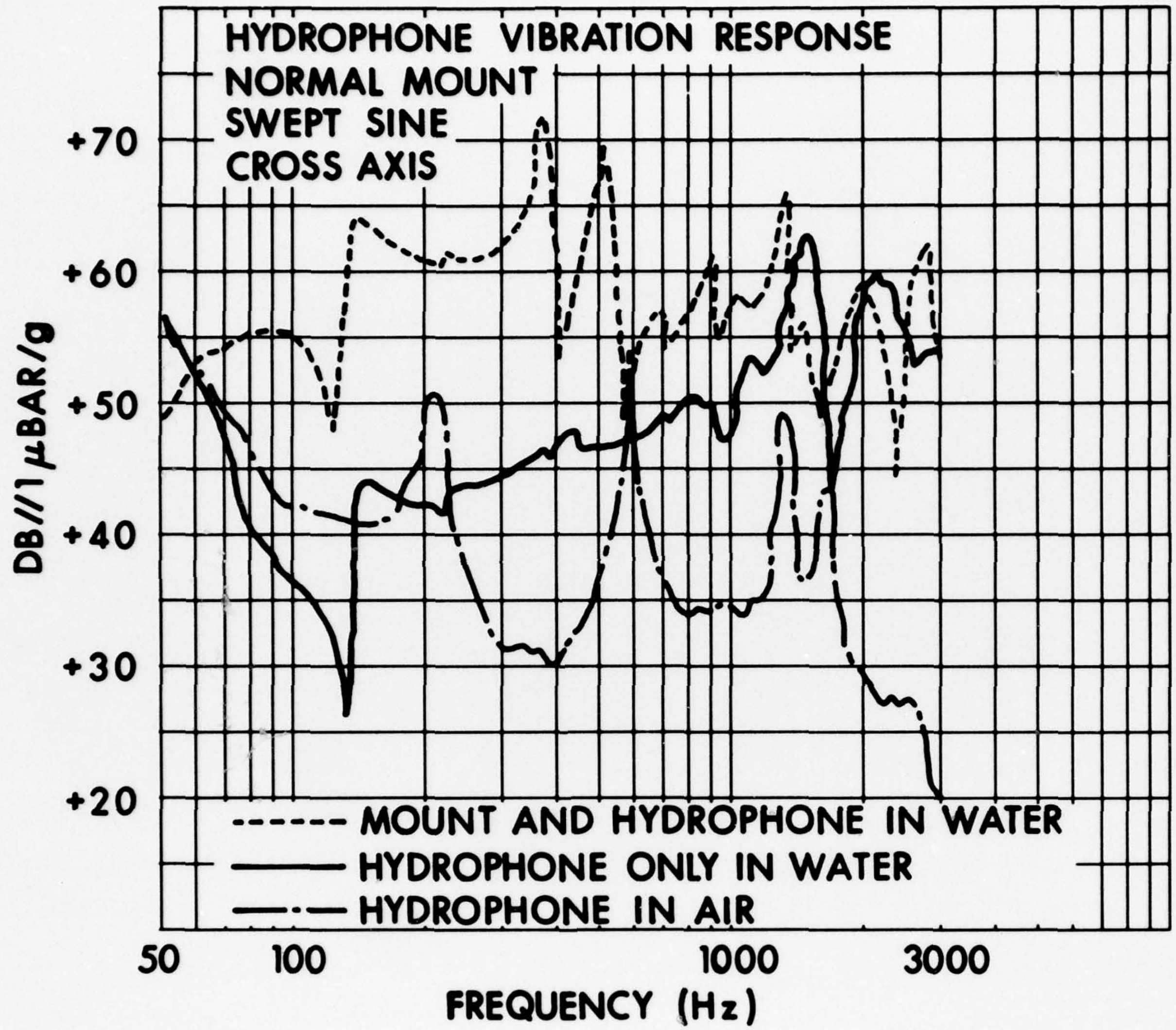

Fig. 2

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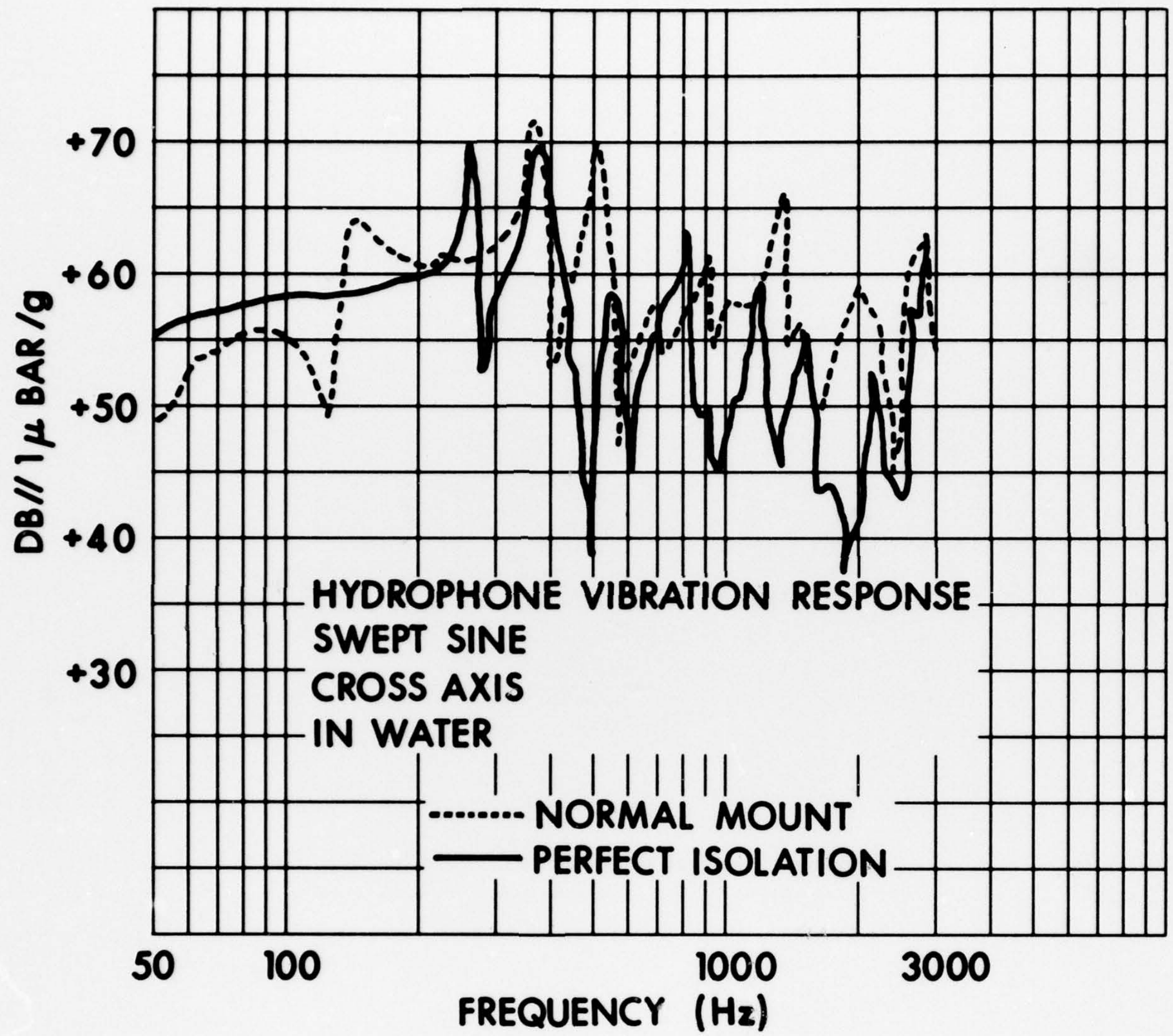

Fig. 3

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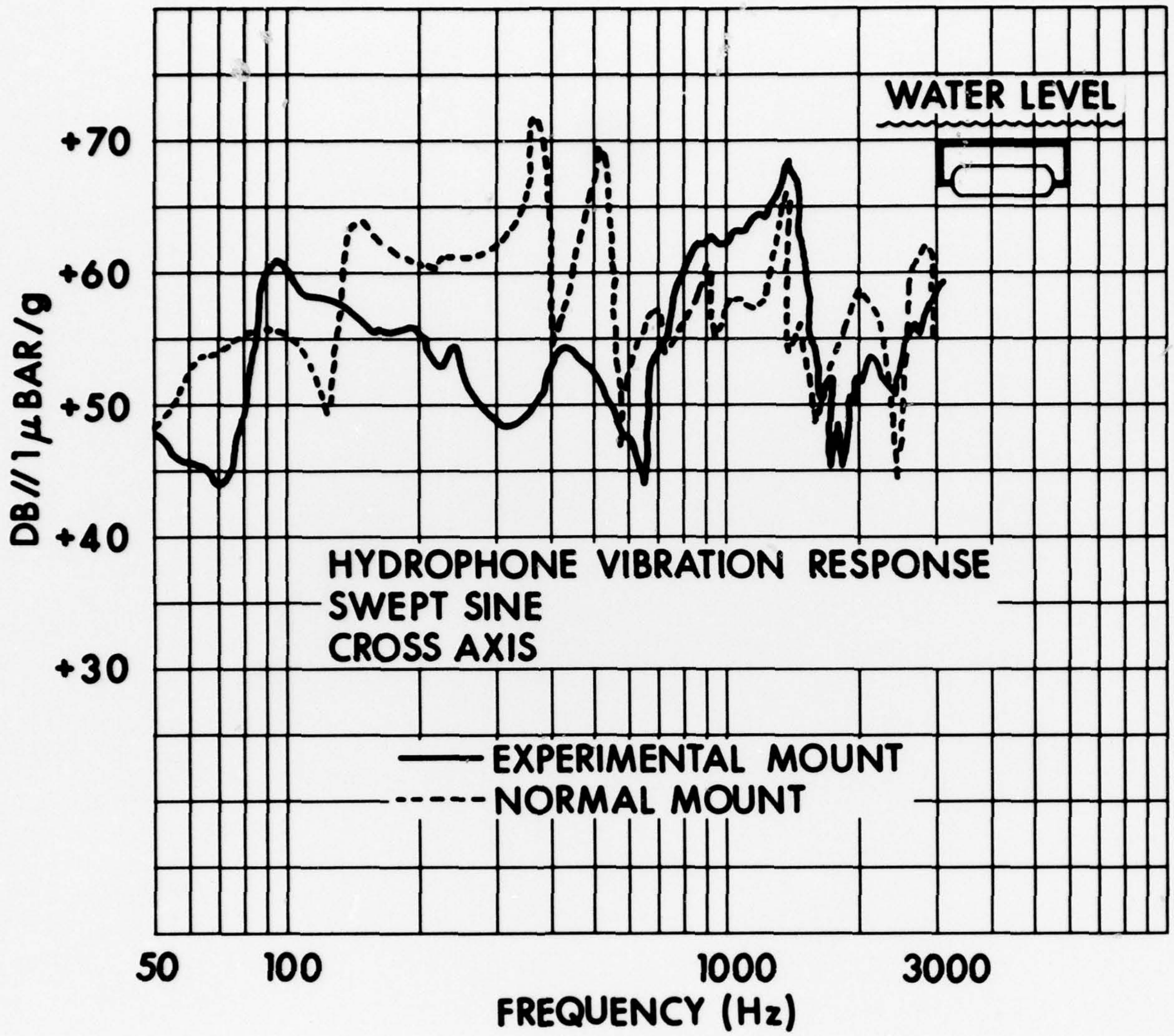

Fig. 4

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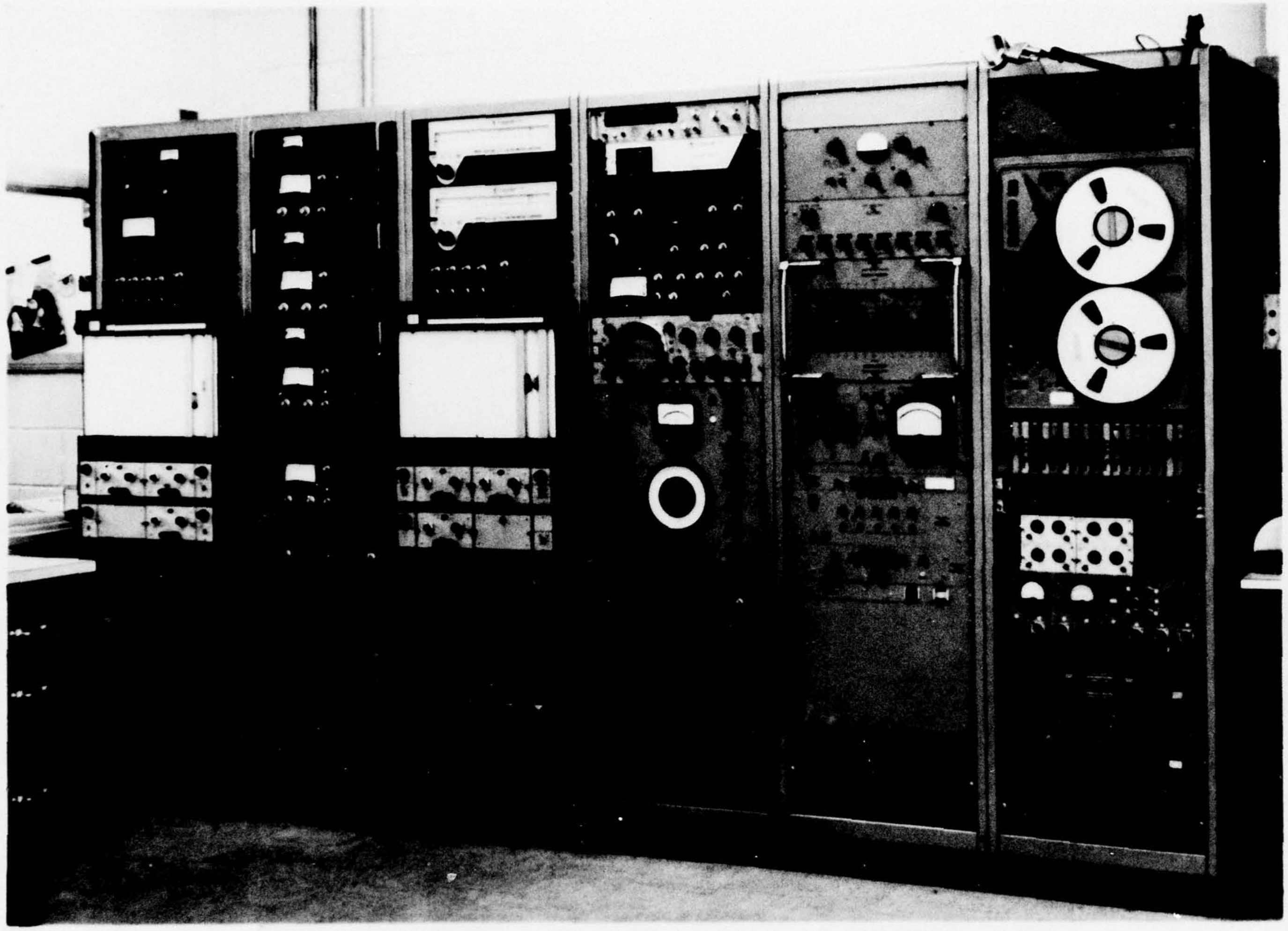

Fig. 5 - USL Transducer Vibration Laboratory Measurement and Analysis System

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